



LtCol David Lucia, USAF
Program Manager
Tactical Technology Office

Propulsion Propels Transformation

You've all heard the old joke, "You can't get there from here."

That relates to the work we're doing at DARPA. We can have all the fine ideas in the world about transformational aircraft, but the key to making any of those ideas work, the only thing that's going to get us from here to there, is focusing on the development of propulsion systems. In other words, propulsion propels transformation.

If you look at the history of aviation, you'll see that every major advance has been preceded by an advance in propulsion some 5 to 7 years earlier.

- At the turn of the last century, it was the Wright Brothers' aluminum block, 12-horsepower, gasoline engine, weighing only 200 pounds, that made the first powered flight possible.
- In the 1940s, it was the Junkers axial flow turbine engine that powered the Messerschmitt 262.
- The SR-71 Blackbird, developed in the 1960s, was "faster than a speeding bullet" because of its turbo-ramjet J58.
- In the 1990s, development of the thrust vectoring F119 with nonafterburning Mach 1.5 cruise made possible today's supersonic, stealthy Raptor.

And as we enter this new century, the Joint Strike Fighter's F35 with turbine shaft-driven lift fans will enable stealthy subsonic cruising and vertical take-off and landing.

This history illustrates my basic point. That's why, at DARPA, when we think about propulsion, we think revolution, not evolution. The future we

imagine for American airpower cannot be built on incremental improvements to existing propulsion systems, especially when the existing systems are themselves incremental improvements from the previous era. The challenges of the post-Cold War era demand a combination of persistence, speed and stealth that is beyond the technology status quo. What we need are quantum leaps in propulsion concepts and designs.

When we look two generations ahead in flight, we see a need to rethink propulsion from the beginning. We must design aircraft around propulsion systems; otherwise, we're designing empty shells or, as I like to say, flying kites.

Looking over the horizon, we see three great challenges in propulsion: a new class of small unmanned air vehicles (UAVs), fast and efficient jet engines, and hypersonic aircraft that provide real capability.

First, small UAVs. I affectionately call it the "flying lawnmower," because that's about the size we're talking. It would have a 10- to 50-horsepower engine, a wingspan of about 10 feet, and carry a payload (a weapon or sensor) of 50 to 100 pounds. Its purpose will be to support ground troops and special operations in variable terrain, including urban environments. For that reason, the engine will have to operate reliably in a wide range of environments, from extreme cold to extreme heat, dry and dusty to humid and rainy.

It has to be quiet with low emissions so as not to alert the enemy and be air-cooled. Because it will be forward deployed with the troops, it has to be able to run on heavy fuel, basically kerosene. In addition, because the UAV is considered

Propulsion Propels Transformation

expendable, the whole thing, including the propulsion system, has to be inexpensive. It can be ugly, ungainly, as inelegant as a flying lawnmower, but it has to be cheap.

That's my first DARPA propulsion challenge: robust, small, quiet and cheap, running on heavy fuel, and extremely fuel efficient. Today we meet only one or two of these requirements at a time. Meeting all these requirements simultaneously may involve increasing fuel-air mixing, actively metering fuel, and improving atomizing techniques. If you think you know how to get from here to there, please come see me.

The second category is fast and efficient jet engines. Traditionally, we build propulsion systems around a single design point in order to reach maximum efficiency in one flight condition. In other words, we build jet aircraft that can do one thing well. Think of the B-1, designed to fly low at supersonic speed to deliver weapons deep in enemy territory, but as we all know, with the Cold War over, we no longer live in a static world. We must design for flexibility—and we must do it now, so we can successfully face whatever threats come our way.

Right now we're very good at designing two types of engines: slow and efficient, or fast and inefficient. Current engines are one or the other, and there are trade-offs in both. We have to transcend trade-offs.

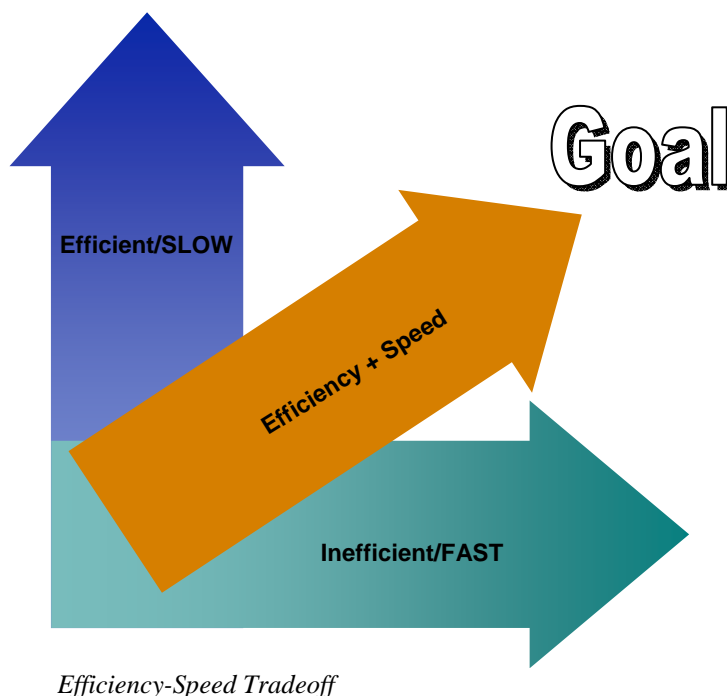
We have to design an engine that gives us efficient supersonics and long endurance, high-payload, high-subsonic capability. Our dream is to be able to loiter like a Global Hawk, streak like a Raptor, be as stealthy as a B-2, and do it all with a single engine. No multiple engine concepts need apply, because lugging around an unused engine is a poor solution.

It may be that the solution lies in a variable bypass engine cycle, a morphing engine with low bypass at supersonic speeds and high bypass when flying subsonic. Still, we're not here to dictate the technology, just lay out the challenge. And the challenge is an engine that is fast, efficient, and flexible. Again, if you think you can get us from here to there, come see me.

Finally, let's talk hypersonics. I'm sure many of you saw the brief flight of the X-43 scramjet a few months ago. It was a beautiful thing to behold, an extraordinary feat of science. Now comes the real

challenge: making hypersonics operational. A functional scramjet engine is truly transformational only if it provides transformational capabilities to the warfighter.

If the hypersonic wave rider is going to enable global reach and introduce a new era of affordable, reusable space access, these operational uses must guide our efforts right from the start. Operational means being able to execute a reasonable military mission. It involves taking off from a runway; getting up to Mach 4.5, the speed at which the scramjet begins to work; being able to slow down and speed up during a mission; and landing at an airport.



Propulsion Propels Transformation

The X-43 basically had a rocket tied to its back to get it going to scramjet speed. That is fine for an experiment, but an operational system may need to accelerate to hypersonic speed multiple times in a mission. The design, development, and integration of an efficient accelerator engine could be the Achilles' heel of the hypersonic platform if not considered early. How are sensors going to react to the plasma shield surrounding the plane? What fuel makes sense for scramjet operations? Do we really want a hydrogen-fueled scramjet or perhaps we should pursue a more practical albeit performance reducing hydrocarbon-fueled system?

You also have to think economics. Why isn't the Concorde flying today? It was simple economics: what we get out of the Concorde just isn't worth the cost to maintain it.

We must think in terms of mission. We must begin designing with the end use in mind. When we

think capabilities, we must aim at solving multiple technology problems in parallel. We must introduce operational constraints to guide how we pursue hypersonics research. The hypersonics propulsion challenge goes beyond the X-43's 30 seconds of powered flight under a single flight condition. We must pioneer a propulsion system that operates across the entire flight envelope, from sea-level static to hypersonic speeds, and it must be able to fulfill specific military missions. That's the third and final challenge: operational hypersonics.

These are tough challenges, I know, but that's what DARPA is all about. How we get from here to there is the question. And the way we answer that question is the key to crossing the next threshold in aviation history and shaping the future of flight.